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WITH TECHNOLOGICAL
INCOMPATIBILITIES IN THE SUPPLY
CHAIN**

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ABSTRACT

Foreign Entry and Spillovers with Technological Incompatibilities in the Supply Chain*

Does foreign entry improve host country productivity and welfare? Existing studies have focused on the role of technology spillovers and backward linkages with domestic suppliers. In this paper, we study how these externalities are affected by technological incompatibilities between foreign and domestic technologies. When foreign technologies require specialized inputs, some local suppliers self-select into production for multinational firms. A decrease in the cost of inputs compatible with the foreign technology has heterogeneous effects. It benefits foreign firms and the most productive downstream domestic firms adopting the foreign technology, and negatively affects firms using the domestic technology. The impact on welfare is positive when we allow for endogenous entry in both upstream and downstream industries, but welfare gains can be negatively related to observed foreign presence at equilibrium. Our model can also reproduce various stylized facts drawn from the empirical literature on vertical and horizontal FDI spillovers.

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1 Introduction

The host-country effects of Foreign Direct Investment (FDI) constitute a traditional concern in international and development economics. One of the consequences of the impressive surge in FDI flows in recent decades has been to bring this debate back to the fore. The current view of the impact of multinationals is optimistic, and the general feeling is that, in many circumstances, their arrival can significantly contribute to the development process in destination economies.¹

Among the potential channels through which FDI is thought to enhance the development process in host economies, spillovers to domestic firms are often cited as a salient one. Nevertheless, we have a far from full understanding of the different channels through which these externalities might operate. Two main possibilities have been advanced in the literature. On the one hand, the introduction of foreign technologies in host countries through multinational production can provide technology adoption opportunities to local firms, for example through demonstration effects (Burstein and Monge-Naranjo, 2009) or labor turnover (Markusen and Ethier, 1996).² On the other hand, the presence of multinational firms might increase the demand for intermediate goods and create backward linkages to local suppliers. The strengthening of the supply chain can then result in forward linkages to local downstream producers in the form of lower input prices (Rodriguez-Clare, 1996; Markusen and Venables, 1999).

Previous studies, however, disregard the possibility that technologies brought in by multinationals require different intermediates goods from those used by domestic firms. In this paper we show that accounting for such differences significantly alters the effect of inward FDI on domestic firms and welfare in the host economy. The effective introduction of new technologies by foreign firms typically requires the development of a supply chain associated with the new technology, which can have adverse effects on firms using inputs compatible with the domestic technology. We derive situations in which domestic firms might be worse off after foreign entry, and show that welfare might be negatively related to foreign presence at equilibrium. However, the introduction of a new type of intermediate goods also triggers the adoption of the foreign technology by domestic firms in both upstream and downstream industries, generating rich interactions between vertical linkages and technology adoption decisions. The predictions that we derive are consistent with an extensive empirical literature on spillovers from foreign direct investment documenting heterogeneous effects of FDI.

Empirical evidence supports the idea that foreign firms tend to operate more advanced technologies that require specialized inputs.³ As an example, in Slovakia, Volkswagen requires all suppliers

¹UNCTAD (2008) tracks the yearly number of changes in national regulations favoring foreign investments. It documents that they have increased almost steadily from a number of 77 in 1992 to 177 in 2006 with a peak of 270 in 2004.

²The preponderant role of multinational firms in knowledge creation is visible in aggregate statistics. Keller (2009) mentions data from the National Science Foundation indicating that in 1999, 83% of all manufacturing R&D in the US was conducted by parents of US multinationals

³In addition, econometric evidence shows that multinationals use more efficient technologies than domestic firms, for both developed and developing economies. Examples for developed countries include the UK (Griffith and Simpson 2001, Criscuolo and Martin 2001), the US (Doms and Jensen, 1998), and Italy (Benfratello and Sembrenelli, 2002). Liu (2006) in China and Jordaan (2008) in Mexico provide examples of developing economies.

to obtain VDA quality certificates,⁴ in concordance with the requirements of the German automotive industry (UNCTAD, 2001 - p 157). Standards are an important requisite for entering global supply chains in the Food industry as well. UNCTAD 2007 (p. 18) reports the case of the European supermarket industry where supermarkets impose suppliers, indistinctive of country of origin, to comply with private protocols of food safety standards, logistical requirements, and process documentation.

A compelling example highlighting the incompatibilities which are central to our analysis is provided by a recent case study on the Mexican soaps, detergents and surfactants industry by Javorcik *et al.* (2006). When Mexico opened its borders to foreign investors, incoming US multinationals brought with them technologies and product formats that were previously unavailable locally (e.g. “compact formulas”). The report documents how suppliers catering to multinationals (some foreign-owned themselves) had to reformulate their inputs by substituting foreign standard ingredients with cheaper ingredients when catering to domestic producers. Moreover, Mexican detergent producers had to incur substantial costs of reformatting their products in order to introduce the foreign technology.

We model interactions between firms in two vertically related industries in equilibrium. Foreign firms enter the downstream industry and compete with domestic firms for local consumers. All downstream producers – domestic and foreign – are assumed to source intermediate inputs locally.⁵ Given technological incompatibilities, suppliers make decisions about which type of intermediate inputs they will produce. Under the assumption that efficiency increases with the set of available intermediate varieties (Ethier, 1982), suppliers’ production choices affect the relative efficiency of the two coexisting technologies. Hence, the adoption of the foreign technology by upstream firms can negatively affect downstream firms using the domestic technology. However, the availability of new types of inputs can benefit those domestic firms that adopt the foreign technology (through the payment of fixed technology adoption costs). In order to study the role of firms’ capabilities in technology adoption and spillovers, we allow domestic firms to be heterogeneous in the spirit of Melitz (2003).⁶ In spite of the complexity of interactions, our framework remains tractable. We solve for the equilibrium with free entry of all three types of firms – foreign, domestic suppliers and domestic downstream producers – and free technology choice for domestic firms in both industries. This setting allows us to study the effects of foreign entry on technology adoption and productivity, firm selection, output reallocations and consumer welfare.

In particular, the model derives several predictions matching key features of recent empirical work on FDI spillovers. A first prediction is that foreign entry increases the average productivity of suppliers: the larger the mass of firms operating the foreign technology, the larger the proportion of suppliers adopting the foreign technology. This result is consistent with the work of Javorcik (2004)

⁴Verband der Automobilindustrie.

⁵Previous work has analyzed the case where domestic and foreign firms differ in the intensity of local sourcing (Rodriguez-Clare, 1996; Markusen and Venables, 1999). We abstract from this possibility to focus the analysis on differences in the type of inputs. Alfaro and Rodriguez-Clare (2004) use data for Latin American countries and find that the “linkage potential” of foreign firms, defined as intermediate inputs used per worker, tends to be similar or higher than that of domestic firms.

⁶We consider heterogeneous downstream domestic firms in the baseline model and we postpone to Section 5 the case of heterogeneous suppliers.

on vertical spillovers and confirmed by a large number of other works.⁷ In turn, foreign technology adoption by local suppliers has heterogeneous effects on the productivity of firms in the downstream industry: it positively impacts firms using the foreign technology but negatively affects firms operating the domestic technology. Empirical papers analyzing the existence of horizontal spillovers tend to find negative or neutral impacts when looking at the average domestic firm. The coexistence of positive vertical with negative or neutral horizontal spillovers seems puzzling at first sight, but becomes a natural outcome within our theoretical framework with technological incompatibilities. Another prediction is that foreign entry should have heterogeneous effects across domestic firms. Our model generates a positive correlation between entrepreneurs' abilities and productivity gains from foreign entry, which has been verified by a number of empirical studies highlighting the role of firms' "absorptive capacity" in the adoption of foreign technologies. Finally, our model provides micro-foundations for empirical findings showing that multinational firms benefit from the presence of other multinationals in the same sector. Evidence of co-agglomeration effects among subsidiaries of multinational firms has been documented by several studies, which emphasized the role of vertical linkages as a driving agglomerating force.⁸

Most of these empirical studies follow a common reduced-form methodology, consisting in regressing a measure of firm-level productivity for domestic firms on a measure of foreign presence at the sector level. Nevertheless, observed foreign presence is an endogenous equilibrium outcome. Entry decisions by multinational firms depend upon structural parameters, such as barriers to foreign entry and the costs of technology adoption in local industries (upstream and downstream). Our model replicates the above empirical results by showing that variations in these underlying parameters generate correlations between the domestic firms' productivity and observed foreign presence.⁹

We also analyze the welfare economics of foreign entry. We find that, in spite of the negative effects of technological incompatibilities, opening to foreign entry results in welfare improvements. Endogenous entry in the downstream industry is essential for this result.¹⁰ We decompose consumer welfare gains from opening the economy to foreign entry into a productivity gain and a variety gain. The productivity gain results from the exit of least productive plants and the reallocation of sales towards more productive firms adopting the foreign technology. There is also a variety gain as foreign firms expand local consumption opportunities by introducing varieties produced with the foreign technology. Interestingly, comparative statics exercises show that the latter source of welfare

⁷We will discuss some of the relevant empirical work in the main text. Nevertheless, the empirical literature on FDI and spillovers is vast. Readers interested in extensive studies may be referred to the survey in our related work Carluccio and Fally (2008a) and in the work by Barba-Navaretti et Venables (2004, Ch. 7), Lipsey (2002) and Alfaro and Rodriguez-Clare (2004), among others.

⁸Alfaro and Chen (2009), Head *et al.* (1995), Head and Mayer (2004), Bobonis and Shatz (2007) and Crozet *et al* (2004). Aitken and Harrison (1999) and Sabiriniova *et al.* (2005) find that the productivity premium of the average multinational increases with the share of other multinationals in the same sector, the former in the case of Venezuela and the latter for the Czech Republic and Russia.

⁹Variations in the cost of foreign entry, the costs of technology adoption in upstream and downstream industries, and efficiency parameters for both technologies generate in our model the desired co-movements in observed foreign presence (measured by the number of active multinationals) and the productivity of local firms.

¹⁰In the working paper version, Carluccio and Fally (2008), we show that when the number of downstream firms is exogenous, foreign entry can result in welfare losses.

gain is positively related to foreign entry, whereas the former is negatively related to observed foreign presence at equilibrium.

Our paper contributes to a small, but growing body of formal literature studying backward linkages between multinational firms and local suppliers. The pioneering study in this area is by Rodriguez-Clare (1996), who develops a model in which multinationals source intermediate goods in a low-wage country: if the intensity with which they source local inputs – the “linkage potential” – is high enough, MNEs create larger net backward linkages that push the underdeveloped region out of the “bad” equilibrium. Markusen and Venables (1999) develop a similar intuition in an industrial organization approach that is closer to ours. As in the work of Rodriguez-Clare (1996), the demand for inputs (backward linkages) created by foreign plants causes entry upstream. This exerts downward pressure on the costs of all downstream firms, generating a forward linkage. Domestic firms, more intensive users of local inputs, gain relatively more. As a consequence, there exist dynamic paths in which foreign firms are eventually forced out and only domestic firms prevail. A recent paper by Alfaro *et al.* (2009) expands this literature to study the role of financial development in linkages creation. In all three papers, however, demand for intermediate goods from multinational firms is directed to all local upstream firms. This assumption contradicts evidence suggesting that multinationals tend to source from a small base of local suppliers presented in, among others, UNCTAD (2001) and OECD (2002). By incorporating this key feature, we improve on this early work and provide a framework better suited to explain empirical results.

Our paper complements the recent work by Lin and Saggi (2007). They study exclusivity contracts from a multinational firm to local suppliers in a model of a two-tier Cournot oligopoly, in which a foreign firm transfers technology to local suppliers. Exclusive contracts restrict technology transfers from the multinational firm within the group of exclusive suppliers, thus leaving domestic producers with a restricted number of suppliers who do not benefit from technology transfers. The framework we develop differs with respect to theirs. Its full tractability allows for the characterization of the industry equilibrium with free entry and free technological choice for all types of firms in both industries, which are key for the main results described in our paper. This unveils a role for different types of externalities between firms and yields additional predictions that match the empirical evidence quite well. First, our model explains positive externalities between multinationals.¹¹ Second, we highlight the role of foreign firms in the transmission of technology to downstream firms: in our model not only suppliers are the recipient of technology transfers, but also domestic competitors, in line with existing evidence. Our paper is also the first to explicitly model heterogeneity among domestic suppliers and competitors to rationalize empirical findings on heterogeneous spillovers and the role of “absorptive capacity”.

The rest of the paper is organized as follows. Section 2 presents the model’s setup and discusses its main assumptions. Section 3 provides a solution of the model when the mixed equilibrium (where both domestic firms and multinationals are active) is stable and relates the theoretical results to the empirical literature on FDI spillovers. Sections 4 and 5 develop respectively the cases of multiple

¹¹By focusing on exclusive contracts between one multinational firm and its suppliers, Lin and Saggi (2007) rule out externalities between multinationals by assumption.

equilibria (when the mixed equilibrium is unstable) and an extension of the baseline model where suppliers are heterogeneous. Section 6 concludes.

2 Setup of the model

We now develop a model of an economy composed of two vertically related industries. In the downstream industry, domestic and multinational firms compete to serve local consumers. In the upstream industry, intermediate goods are assumed to be produced only by local suppliers. We assume that these two industries face a competitive supply of a production factor that we label the “numeraire”.

For the ease of reading, we shall henceforth denote all variables pertaining to the downstream industry in uppercase, as opposed to lowercase for upstream industry variables.

Preferences

There are two technologies for final good production. A domestic “D-technology” with which indigenous firms are endowed, and a foreign “M-technology”, brought-in by multinationals and transferrable to local producers.

Consumer preferences are assumed to be represented by the following two-level CES utility function:

$$U = \left[\left(\int_{\Omega_D} Q_{iD}^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1} \frac{\eta-1}{\eta}} + \left(\int_{\Omega_M} Q_{iM}^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1} \frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

where σ is the constant elasticity of substitution between any two varieties produced with the same technology and η the constant elasticity of substitution between any two varieties produced with different technologies. We make the (natural) assumption that $\sigma > \eta > 1$: goods produced with the same technology are closer substitutes than goods produced under different technologies.¹²

The set of available varieties produced with the local and foreign technologies are denoted by Ω_D and Ω_M respectively. If E denotes the exogenous income spent in the final good industry, the demand curve facing a firm producing variety i with technology $T \in \{D, M\}$ is:

$$Q_{iT} = \left(\frac{P_{iT}}{P_T} \right)^{-\sigma} \frac{E}{P_T} \frac{P_T^{1-\eta}}{P_D^{1-\eta} + P_M^{1-\eta}}$$

where P_{jT} is the price of variety j of technology T and $P_T = \left(\int_{\Omega_T} P_{iT}^{1-\sigma} di \right)^{\frac{1}{1-\sigma}}$ the price index of final goods produced with technology T .

¹²See Ardelean and Lugovsky (2009) for a similar utility function across locally-produced and imported varieties. Since the M-technology is generated in foreign economies, our preference structure can be justified with arguments a la Argminton (1969). Moreover, the possibility that imperfect substitution is due to quality differences could be easily integrated into the model.

The ratio $\frac{P_T^{1-\eta}}{P_D^{1-\eta} + P_M^{1-\eta}}$ represents the share in total consumption of varieties produced with technology T. We also define $\frac{P_M^{1-\eta}}{P_D^{1-\eta}}$ as the relative consumption of varieties produced with the foreign technology.

Production and technological incompatibilities

A central assumption is that intermediate goods are technology-specific. We call D-type inputs those required to produce with the D-technology, and M-type inputs are those produced for use with the M-technology.

Both domestic and multinational firms operate a technology in which intermediate varieties are assumed to be horizontally differentiated and to enter final production as a CES composite, as in Ethier (1982). For the simplicity of exposition, we assume that the elasticity of substitution between any two varieties is equal to the elasticity of substitution between final goods produced with the same technology σ . Notice however that the model remains tractable and the results similar should we allow for differences in these elasticities.¹³ Under these assumptions, the technology-specific production function operated by the typical downstream firm i is

$$Q_{Ti} = \Phi_i \left(\int_0^{n_T} q_{Tij}^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}}$$

where n_T is the number of input varieties for technology T, q_{Tij} the quantity of input variety j of technology T consumed by the downstream firm i . Φ_i is the ability of the firm i , defined as the quantity of output that a firm can produce using a unit of the CES aggregator of intermediate inputs.

This specification of technology aims at capturing the idea that the division of labor enhances production efficiency (see Rodriguez-Clare, 2005 and Ciccone and Matsuyama, 1993). The larger the set of available intermediate varieties, the lower the costs associated with the use of each technology.

The costs of intermediates for a firm producing under technology T, that we label Λ_T , is defined as the inverse of the price index of the bundle of inputs compatible with the T-technology:

$$\Lambda_T = \left(\int_0^{n_T} p_{iT}^{1-\sigma} d_i \right)^{1/(\sigma-1)}$$

Entry into the downstream industry

Both domestic and multinational firms can enter the downstream industry upon payment of a fixed entry cost. Domestic firms are assumed to be heterogeneous in the spirit of Melitz (2003). Upon payment of a fixed cost F_E (measured in terms of the numeraire), firms discover the value of their

¹³It is also possible to reformulate the model and assume that the production function is Cobb-Douglas and only a fraction β of inputs are specific to each technology. The assumption would weaken the condition under which a mixed equilibrium exists.

“ability” Φ drawn from a continuous cumulative distribution $G(\Phi)$.¹⁴ As in a bulk of recent work (e.g. Helpman, Melitz and Yeaple, 2004 and Chaney, 2008), we give $G(\Phi)$ the form of a Pareto distribution:

$$G(\Phi) = 1 - \Phi^{-k}$$

where the shape parameter k is assumed to satisfy $k > \sigma - 1$. This assumption yields tractable solutions while fitting well the observed distributions of firm size (see Axtell, 2001, and Helpman, Melitz and Yeaple, 2004).

Notice that Φ is independent of the unit costs associated with the availability of inputs. Firm-level productivity, defined as the ratio of output to *expenditures* on inputs, equals $\Phi\Lambda_T$.

Once a firm has discovered its ability, it decides whether to exit or to stay in the market and produce. Production under technology D requires a fixed cost F_D in terms of the numeraire and the use of intermediate inputs whose price is external to the firm. Domestic firms are allowed to also produce with the foreign M-technology upon payment of an additional fixed cost F_M . This possibility is assumed to be absent in autarky. This assumption is aimed at capturing the role of FDI as an international conductor of technology: the presence of multinationals provides domestic firms with access to the foreign technology.

Multinationals are assumed to enter the host country to serve the local market. Multinational entry is costly: it requires a fixed cost of F_{MNE} units of the numeraire. The production structure is assumed to be similar to that of domestic firms, resulting in that each multinational chooses to produce a different variety in equilibrium. For simplicity, foreign firms are assumed to be homogeneous in terms of ability, which is represented by Φ_{MNE} .¹⁵

For future reference, we construct indices X_M and X_D representing the mass of firms operating each new technology, weighed by their ability Φ :

$$\begin{aligned} X_M &\equiv \int_{\Omega_M} \Phi_i^{\sigma-1} di \\ X_D &\equiv \int_{\Omega_D} \Phi_i^{\sigma-1} di \end{aligned}$$

X_M includes all multinationals as well as domestic firms that choose to adopt the foreign technology.

Given that total productivity is the combination of each firm’s ability Φ_i and the availability of inputs Λ_T , we can express relative consumption shares as a function of both the relative mass of firms $\frac{X_M}{X_D}$ and the relative price of inputs $\frac{\Lambda_M}{\Lambda_D}$:

$$\frac{P_M^{1-\eta}}{P_D^{1-\eta}} = \left(\frac{X_M}{X_D}\right)^{\frac{\eta-1}{\sigma-1}} \left(\frac{\Lambda_M}{\Lambda_D}\right)^{\eta-1} \quad (1)$$

Both $\frac{X_M}{X_D}$ and $\frac{\Lambda_M}{\Lambda_D}$ are endogenous and will be determined at equilibrium. $\frac{\Lambda_M}{\Lambda_D}$ will be determined by the technological choice of suppliers, whereas $\frac{X_M}{X_D}$ by the entry of domestic downstream firms and

¹⁴For simplicity, and as usual in the firm heterogeneity literature, the distribution is assumed to be common knowledge.

¹⁵This assumption is made for analytical convenience, but note however that this setting is equivalent to one where multinational firms draw a random productivity after paying F_{MNE} and then produce.

multinationals, as well as technology adoption by domestic downstream firms.

Upstream industry

We now turn to upstream producers. Production of intermediates of technology $T \in \{D, M\}$ requires a fixed cost f_T measured in terms of the numeraire. In turn, λ_T represents the quantity of inputs produced with one unit of the numeraire with technology T, and $\lambda_M > \lambda_D$. The latter inequality captures the idea that the foreign technology is more efficient (but its incorporation can be costlier).

Each supplier produces a different variety. Given this productive structure, n_D and n_M represent both the number of suppliers and the number of varieties available for each technology.

The availability of specialized inputs affects the relative costs associated with each of the two technologies, Λ_M/Λ_D . To appreciate this point, we express the ratio of costs as a simple function of the exogenous technological advantage of the foreign technology, λ_M/λ_D , and the relative number of input varieties n_M/n_D available for each technology:

$$\frac{\Lambda_M}{\Lambda_D} = \frac{\lambda_M}{\lambda_D} \left(\frac{n_M}{n_D} \right)^{\frac{1}{\sigma-1}} \quad (2)$$

3 Equilibrium

3.1 Equilibrium in the upstream industry

In order to highlight the key mechanisms of our model, it is instructive to first solve a partial equilibrium version where downstream market structure is given exogenously (that is, by taking the number of downstream firms, their productivity, and their technological choices as given). Analytically this amounts to taking X_M and X_D as given and solving for suppliers' optimal choices as a function of these variables. We postpone the solution of the complete system to Section 3.2.

Denote by n_T the number of suppliers choosing to produce inputs compatible with technology T. Given free entry and free technological choice, an equilibrium is defined by a pair (n_D, n_M) such that the profits associated with each technology are zero. Equilibrium in the upstream industry is defined by:

$$\begin{cases} \pi_M(n_D, n_M) = 0 \\ \pi_D(n_D, n_M) = 0 \end{cases}$$

where π_T represents profits accruing from producing in T-type inputs, net of fixed costs f_T .

Total demand for T-type inputs depends on the market share of downstream firms using the T-technology. Note that profits for a supplier choosing $T \in \{D, M\}$ depend negatively on the number of suppliers choosing T as well (affecting the slope of the perceived demand curve via business stealing effects) and positively on total demand for T-type inputs (affecting the position of the perceived demand schedule):

$$\pi_T = \frac{\alpha_1 E}{n_T} \frac{P_T^{1-\eta}}{P_M^{1-\eta} + P_D^{1-\eta}} - f_T$$

where α_1 is a constant.¹⁶ At zero-profit, we obtain that the relative number of suppliers equals relative fixed costs weighted by the relative share of technologically differentiated varieties in consumption: $\frac{n_M}{n_D} = \frac{f_D}{f_M} \frac{P_M^{1-\eta}}{P_D^{1-\eta}}$.

However, demand facing downstream firms using technology T is itself a function of the number of suppliers choosing to produce for the T-technology. As equation (2) shows, the relative efficiency of both technologies is determined not only by supplier productivity but also by their relative number. The larger the set of varieties available for one technology, the larger the efficiency of downstream plants operating the technology.

Incorporating expressions (1) and (2) into the free entry equations, we obtain the unique pair (n_M, n_D) characterized by:

$$\frac{n_M}{n_D} = \left(\frac{\lambda_M^{\eta-1} f_D}{\lambda_D^{\eta-1} f_M} \right)^{1+\theta} \left(\frac{X_M}{X_D} \right)^\theta \quad (3)$$

where $\theta \equiv \frac{\eta-1}{\sigma-\eta} > 0$.

At equilibrium, the proportion of suppliers choosing the M-technology is larger the higher the relative efficiency of the foreign technology (first term of the first parentheses). It is also higher the larger the mass of firms producing with the M-technology (second parentheses). The intuition is that the larger is the share of consumption that is devoted to goods produced under the M-technology, the more attractive technology upgrading is for suppliers. This reduces the cost of intermediates for plants using the foreign technology and further increases the consumption share captured by these plants.

Notice that X_M is increasing in both the number of multinationals and the proportion of domestic firms adopting the foreign technology. This points to a positive externality among firms using the foreign technology and highlights a central idea of this paper, which is that technological similarities among plants are a source of strategic complementarities. Multinationals play a key role in the development of such complementarities. In order to operate in the local market they create backward linkages with local suppliers, putting pressure on to develop a more complete supply chain attached to the modern technology. The increased availability of varieties compatible with the foreign technology reduces the production costs of plants using the M-technology, a forward linkage effect.

Conversely, it has a negative effect on the number of suppliers producing with the domestic technology which, in turn, negatively affects domestic firms relying on the domestic technology. If we denote by n_A the number of suppliers in “autarky”, i.e. when the foreign technology is not available, we can show that:¹⁷

$$\frac{n_D}{n_A} = \left(1 + \frac{f_M n_M}{f_D n_D} \right)^{-1} < 1$$

It decreases with $\frac{n_M}{n_D}$: the larger the fraction of suppliers adopting the new technology, the lower the number of suppliers operating with the domestic technology. Moreover, we can also verify that the

¹⁶ α_1 is determined by σ and η .

¹⁷We can also show that $\frac{n_D}{n_A} = \frac{P_D^{1-\eta}}{P_D^{1-\eta} + P_M^{1-\eta}}$. The decrease in the number of suppliers producing with the domestic technology corresponds to the decline in the consumption share in goods produced with the domestic technology.

total number of suppliers $n_M + n_D$ also decreases with $\frac{n_M}{n_D}$.

Incorporating suppliers' optimal choices – plugging (3) into (2) – we obtain a simple relationship between the composition of the downstream industry and the relative costs of the foreign and domestic technologies:

$$\frac{\Lambda_M}{\Lambda_D} = \left(\frac{\lambda_M}{\lambda_D}\right)^{1+\theta} \left(\frac{X_M}{X_D}\right)^{\frac{\theta}{\sigma-1}} \left(\frac{f_D}{f_M}\right)^{\frac{\theta}{\eta-1}} \quad (4)$$

Notice that $1+\theta$ reflects the elasticity of the relative advantage of downstream firms using the M-technology ($\frac{\Lambda_M}{\Lambda_D}$) to relative efficiency of the M-technology ($\frac{\lambda_M}{\lambda_D}$). As $1+\theta > 1$, differences in technological efficiency amplify differences in terms of relative costs (i.e. taking into account the costs of intermediates), because the more productive technology attracts more suppliers, resulting in a wider range of intermediate varieties.

Thus, the model gives rise to a mechanism by which the suppliers' technological specialization creates a causal link from technological to “real” advantages for foreign plants. Note that industry-wide equilibrium effects add to the more conventional business stealing effects. Given the coexistence of two incompatible technologies, backward and forward linkages are limited to the scope of firms using the same technology and do not spread to all firms in the industry. We summarize these findings in the following proposition.

Proposition 1 *The productivity premium of the foreign technology $\frac{\Lambda_M}{\Lambda_D}$ is magnified by the endogenous specialization of suppliers and increases with the relative proportion of firms $\frac{X_M}{X_D}$ using the foreign technology in the downstream sector.*

Through suppliers' self-selection, the relative consumption of varieties produced with the foreign technology depends on both its technological advantage and the relative predominance of M-plants:

$$\frac{P_M^{1-\eta}}{P_D^{1-\eta}} = \left(\frac{\lambda_M^{\sigma-1} f_D X_M}{\lambda_D^{\sigma-1} f_M X_D}\right)^\theta \quad (5)$$

The larger the weight of firms producing with the foreign technology, the larger the number of suppliers self-selecting into production of inputs for the M-technology. The resulting cost advantage for plants operating the foreign technology lowers prices and prompts consumers to substitute in favor of varieties produced with the M-technology.

The strength of this effect depends crucially on the value of θ . For high values of θ , an increase in the relative attractiveness of the foreign technology from the suppliers' viewpoint (higher relative efficiency or higher relative demand by downstream firms) results in large changes in relative costs and therefore in a strong adjustment of consumption towards varieties produced with the foreign technology. The parameter $\theta \equiv \frac{\eta-1}{\sigma-\eta}$ is large when the elasticity of substitution between varieties produced with each technology is large (high η). The more differentiated goods are in the eyes of consumers, the more sensitive is the composition of consumption to changes in relative costs. It is

also large when intermediates are weak substitutes (low σ), i.e. when the efficiency of downstream firms is very sensible to the availability of intermediate inputs.

3.2 Equilibrium in the downstream industry

In the previous section we have treated X_M and X_D as exogenous. But they are the outcome of individual firms' entry and technology adoption choices in the downstream industry, which are itself determined by the choices of suppliers. We now allow for free entry and free technology adoption to solve for the industry equilibrium.

Profits generated by the typical active plant producing with technology T can be expressed as a function of the mass of firms using the same technology (X_T) and the share of consumption that is spent on varieties produced under the same technology:

$$\Pi_{Ti}(\Phi_i) = \frac{\Phi_i^{\sigma-1} \alpha_2 E}{X_T} \frac{P_T^{1-\eta}}{P_M^{1-\eta} + P_D^{1-\eta}} - F_T \quad (6)$$

where α_2 is a constant.¹⁸ A similar expression is obtained for multinational firms with the corresponding ability Φ_{MNE} and fixed cost F_{MNE} parameters.

Upon entry, domestic producers choose whether to produce only with the domestic technology or with both. A domestic firm with an ability Φ will adopt technology $T \in \{D, M\}$ only if associated profits $\Pi_T(\Phi)$ are positive. For each $T \in \{D, M\}$, profits are strictly increasing in ability Φ , and the presence of fixed costs ensures that for low values of Φ production is not profitable. Technological adoption in the downstream sector is thus driven by a self-selection mechanism. For each technology there exists a cutoff level Φ_T such that the domestic firm with ability Φ_T is indifferent between producing with technology T or not. These two thresholds are implicitly defined by $\Pi_D(\Phi_D) = 0$ and $\Pi_M(\Phi_M) = 0$. Notice that firms with ability above both thresholds Φ_D and Φ_M produce with both technologies.¹⁹

Let N_{MNE} and N_D the number of multinational and domestic downstream firms that pay the entry cost and discover their ability parameter Φ . Given that firms have knowledge of the underlying cumulative distribution $G(\Phi)$, they anticipate ex-post profits and thereby make entry decisions calculating the ex-ante expected gains from entry. With an unbounded pool of potential entrants, expected profits will adjust until their value net of fixed entry costs F_E is driven to zero. The free-entry condition for domestic firms writes:

$$E[\Pi] = \int_{\Phi_D}^{\infty} \Pi_D(\Phi) dG(\Phi) + \int_{\Phi_M}^{\infty} \Pi_M(\Phi) dG(\Phi) = F_E$$

Similarly, multinationals are assumed to enter the host country as long as expected profits are positive. This induces a free entry condition equating profits (net of fixed costs of entry) to zero, $\Pi_{MNE} = 0$. Note that multinationals make their entry decisions by anticipating that some local

¹⁸ α_2 is determined by σ and η

¹⁹All of our results remain qualitatively similar if we assume that firms cannot incorporate and use both technologies.

firms will imitate their technology.²⁰

Under these specifications, equilibrium is formally defined by the following system of equations:

$$\pi_M = 0 \quad (7)$$

$$\pi_D = 0 \quad (8)$$

$$E[\Pi] - F_E = 0 \quad (9)$$

$$\Pi_D(\Phi_D) = 0 \quad (10)$$

$$\Pi_M(\Phi_M) = 0 \quad (11)$$

$$\Pi_{MNE} = 0 \quad (12)$$

The set of unknowns is composed of the following 6-tuple: $(n_D, n_M, N_D, N_{MNE}, \Phi_D, \Phi_M)$. These are, respectively: the number of upstream varieties for the D-technology, for the M-technology, the number of domestic final producers paying the entry cost, the number of multinationals, and the cutoff productivity that defines the adoption of the D-technology by domestic producers, and the adoption of the M-technology.

Multiplying the number of multinational and domestic downstream firms N_{MNE} and N_D by the share of firms producing at equilibrium with each technology, weighted by their ability Φ , we find indices X_M and X_D for the mass of firms using the new technology and the domestic technology respectively. They equal:

$$\begin{aligned} X_M &= N_D \int_{\Phi_M}^{\infty} \Phi^{\sigma-1} dG(\Phi) + N_{MNE} \Phi_{MNE}^{\sigma-1} \\ X_D &= N_D \int_{\Phi_D}^{\infty} \Phi^{\sigma-1} dG(\Phi) \end{aligned}$$

Productivity thresholds and technology adoption

As already discussed, there are two ability thresholds. The survival threshold Φ_D is the ability level making a firm indifferent between producing under the domestic technology or exiting. The “adoption threshold” Φ_M is the ability level making a firm indifferent between adopting the foreign technology or not. Both thresholds are endogenous at equilibrium.

Equations (11) and (12) combined together provide an expression for Φ_M :

$$\Phi_M = \left(\frac{F_M}{F_{MNE}} \right)^{\frac{1}{\sigma-1}} \Phi_{MNE} \quad (13)$$

Higher fixed costs of technology adoption raise the minimum ability level required for adoption to be profitable. Higher fixed costs of multinational entry or lower multinational productivity decrease it, through reduced competition effects.

²⁰For the moment, we assume a positive number of multinational firms entering the market. The fact that foreign firms can be forced out in equilibrium is equivalent to the case of Markusen and Venables (1999) and will be discussed later.

The free entry equations for domestic firms (9) to (11) provide a condition on both Φ_D and Φ_M :

$$F_E = \left(\frac{k}{\sigma-1} - 1\right) \left[F_D \Phi_D^{-k} + F_M \Phi_M^{-k} \right] \quad (14)$$

Expressions (13) and (14) determine both Φ_D and Φ_M , and thus the share of domestic firms that produce at equilibrium and the share that adopt the foreign technology. We obtain the following expression for Φ_D :

$$\Phi_D = \left(\frac{k}{\sigma-1} - 1\right)^{\frac{1}{k}} \left(\frac{F_D}{F_E}\right)^{\frac{1}{k}} \left[1 - \left(\frac{k}{\sigma-1} - 1\right) \frac{F_{MNE}^{\frac{k}{\sigma-1}}}{F_E F_M^{\frac{k}{\sigma-1} - 1}} \Phi_{MNE}^{-k} \right]^{-\frac{1}{k}} \quad (15)$$

Finally, it proves useful to set a benchmark “autarky” situation where the industry is only populated by domestic firms producing under the local technology (technically this amounts to assuming $F_M = F_{MNE} = \infty$). The survival threshold in this case becomes $\Phi_A = \left(\frac{k}{\sigma-1} - 1\right)^{\frac{1}{k}} \left(\frac{F_D}{F_E}\right)^{\frac{1}{k}}$.

Throughout, we focus on the case $\Phi_D < \Phi_M$: that is, the more productive firms self-select into technology adoption. This situation matches empirical evidence on spillovers, as discussed in Section (3.3). The condition required for this ordering to hold in equilibrium is the ability gap between domestic firms and foreign firms to be large enough.²¹ Our results are summarized in the following proposition:

Proposition 2 *The survival threshold, Φ_D :*

- (i) *decreases with the cost of adoption of the foreign technology,*
- (ii) *and increases with the cost of entry for multinational firms.*
- (iii) *In addition, $\frac{\Phi_D}{\Phi_A}$ increases with the dispersion of abilities (i.e. decreases with k).*

Of particular interest is the effect that the cost of foreign technology adoption has on firm survival. When technology adoption is prohibitively costly for domestic firms, the proportion of firms adopting the foreign technology Φ_M^{-k} tends to zero and equation (14) reduces to $F_E = \left(\frac{k}{\sigma-1} - 1\right) F_D \Phi_D^{-k}$. Hence, the survival threshold does not depend on multinational firm entry and it is the same as in autarky.

When technology adoption is possible, we obtain that $\frac{\Phi_D}{\Phi_A} > 1$: survival is tougher. Along the same lines, we find that Φ_D increases monotonically when F_M decreases. The intuition is the following. The possibility of adopting the new technology increases profits, *ceteris paribus*, compared to producing only with the domestic technology. The lower the cost of technology adoption, the larger the expected profits and the larger the number of domestic entrants at equilibrium. The tougher competition among domestic firms then raises the survival threshold Φ_D .

Further, the survival threshold depends on the cost of multinational entry when the cost of technology adoption is not prohibitive ($F_M < \infty$). We find that $\frac{\partial \Phi_D}{\partial F_{MNE}} > 0$. This result is counterintuitive: increasing entry costs of multinational firms reduces the probability of survival of domestic

²¹Analytically the condition writes: $\left(\frac{\Phi_{MNE}}{\Phi_A}\right)^{-k} < \left(\frac{F_D}{F_M + F_D}\right) \left(\frac{F_M}{F_{MNE}}\right)^{\frac{k}{\sigma-1}}$, where $\left(\frac{\Phi_{MNE}}{\Phi_A}\right)^{-k}$ is the fraction of firms in autarky with ability larger than the one of multinational firms.

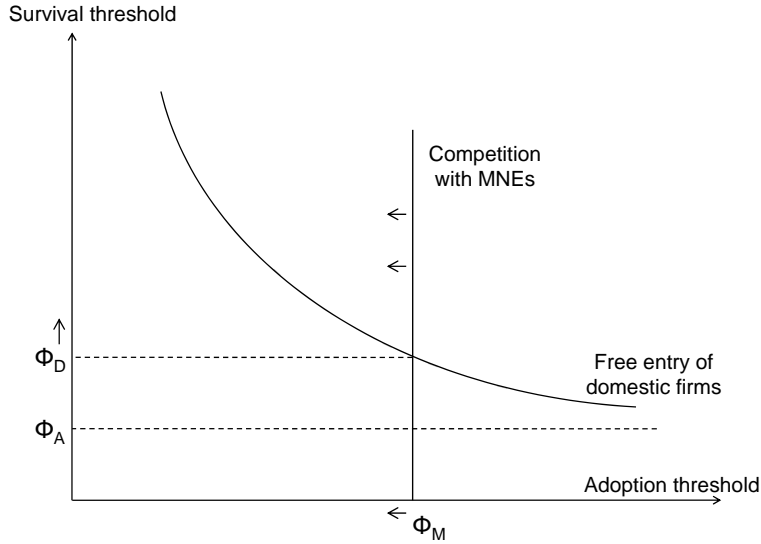


Figure 1: Technology adoption and survival threshold: effect of a increase in F_{MNE}

firms. Figure 1 provides a graphical representation. It derives from the fact that multinationals compete directly with domestic firms producing with the foreign technology. When F_{MNE} increases, competition for consumers of varieties produced with the foreign technology favors domestic firms and Φ_M decreases (this effect is illustrated by the shift of the vertical line to the left). It induces higher expected profits for domestic firms upon entry, and thus increases the number of domestic entrants. As the number of domestic firms producing goods with the D-technology goes up, survival is tougher and the threshold Φ_D increases.

As illustrated in point (iii) in Proposition 2, ability dispersion also affects the free entry conditions and the survival threshold, since technology adoption choices depends on firm ability. Comparing with autarky, we obtain that $\frac{\Phi_D}{\Phi_A}$ increases with ability dispersion. When dispersion increases, the relative number of domestic firms with large ability parameter which are active at equilibrium increases. Those firms adopt the new technology and have higher profits. This implies that the larger the dispersion in ability, the larger the expected profits and the larger the number of entrants at equilibrium. The tougher competition among domestic firms then raises the survival threshold Φ_D .

Finally, the ratio $(\Phi_M/\Phi_D)^{-k}$ provides the fraction of surviving domestic firms adopting the foreign technology. It satisfies:

Proposition 3 *The fraction of firms adopting the foreign technology, $(\Phi_M/\Phi_D)^{-k}$:*

- (i) *increases with the cost of entry for multinational firms.*
- (ii) *decreases with the cost of adoption of the foreign technology.*

These results are intuitive.²² Because of the direct competition with multinational firms, profits of domestic firms adopting the foreign technology increase with the cost of foreign entry. On the contrary, increasing the cost of technology adoption decreases profits related to the adoption of the foreign technology compared to the domestic technology.

Equilibrium consumption shares

Using zero-profit conditions for domestic (10) and foreign firms (12), we can obtain an equilibrium relationship between relative shares in total consumption of goods produced and the relative mass of firms X_M/X_D :

$$\frac{X_M}{X_D} = \frac{\Phi_{MNE}^{\sigma-1} F_D}{\Phi_D^{\sigma-1} F_{MNE}} \times \frac{P_M^{1-\eta}}{P_D^{1-\eta}} \quad (16)$$

The relationship is increasing. The larger the share of consumption goods produced with a given technology, the larger be the mass of firms operating with that technology at equilibrium. This channel, that we label *entry*, operates through the market for final goods with free entry.

Similarly, equation (5) reflecting equilibrium in the upstream industry gives relative consumption $\frac{P_M^{1-\eta}}{P_D^{1-\eta}}$ as function of the mass of firms in each technology $\frac{X_M}{X_D}$. This is the *linkages* channel: the larger the relative mass of firms producing with the foreign technology, the larger the demand for compatible inputs, and the larger the number of suppliers self-selecting into production of such inputs. This increases the cost advantage of plants using the foreign technology and increases their share in total consumption. As discussed in Section 3.1, the strength of this effect depends crucially on the value of θ . For large values of it, a increase in the relative mass of downstream firms using one technology has a strong effect on the availability of inputs of the same technology.

The intersection of both channels pins down relative consumption shares and the relative mass of firms in equilibrium. We now focus on the case with stable solution, which arises when θ is not too large. To be more precise, it requires that $\theta < 1$ such that the business stealing effect from equation (16) dominates the linkages effect from equation (5).²³ This case is shown in Figure 3.2. When the relative mass of firms $\frac{X_M}{X_D}$ increases compared to equilibrium, competition reduces profits among firms producing with the foreign technology and $\frac{X_M}{X_D}$ tends to decline. Conversely, when the relative mass of firms $\frac{X_M}{X_D}$ decreases compared to equilibrium, competition reduces profits among firms producing with the domestic technology and $\frac{X_M}{X_D}$ tends to increase.

At the intersection between the two curves, $\frac{P_M^{1-\eta}}{P_D^{1-\eta}}$ and $\frac{X_M}{X_D}$ are determined by:

$$\frac{P_M^{1-\eta}}{P_D^{1-\eta}} = \left(\frac{\Phi_{MNE}^{\sigma-1} F_D}{\Phi_D^{\sigma-1} F_{MNE}} \frac{\lambda_M^{\sigma-1} f_D}{\lambda_D^{\sigma-1} f_M} \right)^{\frac{\theta}{1-\theta}} \quad (17)$$

²²Formally, they are obtained by combining equations (13) and (15).

²³When only a fraction $\beta < 1$ of expenditures in inputs is specific to each technology, the stability condition is more likely verified for different elasticities σ and η . However, even if $\beta < 1$, stability requires that η is smaller than σ .

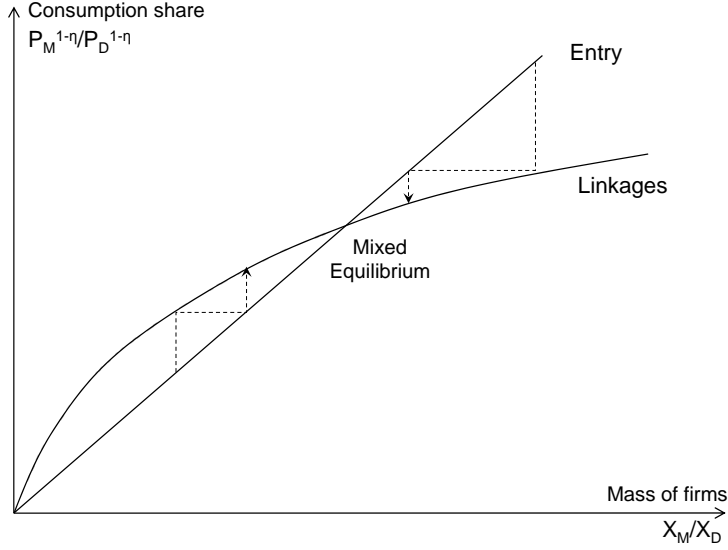


Figure 2: Linkage versus business stealing effects: stable mixed equilibrium ($\theta < 1$)

$$\frac{X_M}{X_D} = \left(\frac{\Phi_{MNE}^{\sigma-1} F_D}{\Phi_D^{\sigma-1} F_{MNE}} \right)^{\frac{1}{1-\theta}} \left(\frac{\lambda_M^{\sigma-1} f_D}{\lambda_D^{\sigma-1} f_M} \right)^{\frac{\theta}{1-\theta}} \quad (18)$$

Notice that F_M , the fixed cost of technology adoption, does not appear in either of the two expressions above. Hence, the cost of technology adoption affects the equilibrium consumption share and the equilibrium relative mass of firms $\frac{X_M}{X_D}$ only through Φ_D . Since a decrease in F_M has a positive effect on Φ_D , we obtain, surprisingly, that technology adoption has a positive effect on the relative consumption share for goods produced with the domestic technology. The intuition is that the possibility of foreign technology adoption induces a greater entry by domestic firms and a tougher competition for multinational firms, which, in turn, increases the number of firms producing with the domestic technology.

Comparative statics exercises on the equilibrium relative consumption shares and the relative mass of plants producing with the foreign technology provide the following results:

Proposition 4 *The equilibrium relative consumption of varieties produced with the foreign technology $\frac{P_M^{1-\eta}}{P_D^{1-\eta}}$ and the relative mass of plants producing with the foreign technology $\frac{X_M}{X_D}$:*

- (i) *decrease with the cost of entry for multinational firms.*
- (ii) *increase with the cost of technology adoption for downstream domestic firms.*
- (iii) *decrease with the cost of technology adoption for suppliers.*

Equilibrium number of entrants

From the equilibrium consumption share and free entry equations, we can calculate absolute values of X_D and X_M and thus the number of domestic and multinational firms at equilibrium. Concerning

domestic firms, we obtain:

$$N_D = \Phi_D^k \frac{\alpha_3 E}{F_E} \frac{P_D^{1-\eta}}{P_D^{1-\eta} + P_M^{1-\eta}} < 1$$

where α_3 is a constant. At equilibrium, the number of domestic firms that survive and produce is equal to $N_D \Phi_D^{-k}$, and is smaller than in autarky:

$$\frac{N_D \Phi_D^{-k}}{N_A \Phi_A^{-k}} = \frac{P_D^{1-\eta}}{P_D^{1-\eta} + P_M^{1-\eta}} < 1 \quad (19)$$

When foreign technology adoption is prohibitively costly for domestic firms ($F_M = \infty$), we have previously shown that the productivity threshold Φ_D is the same as under autarky. In this case, the number of entrants relative to autarky is given by the consumption share of goods produced with the domestic technology. Hence, $N_D < N_A$. However, N_D is negatively related to F_M : technology adoption raises expected profits and prompts firm entry, in spite of the competition effect of multinational presence.

Concerning the number of multinational firms, we can verify similar qualitative comparative statics as for the consumption share for goods produced with the foreign technology. In particular we obtain:

Proposition 5 *The equilibrium number of multinationals N_{MNE} :*

- (i) *decreases with the cost of entry for multinational firms.*
- (ii) *increases with the cost of technology adoption for downstream domestic firms.*
- (iii) *decreases with the cost of technology adoption for suppliers.*

The intuition for (i) is straightforward. We have shown that higher fixed costs of entry for multinationals decreases the relative mass of firms using the foreign technology. Moreover, increasing fixed cost of entry for multinationals also increases the proportion of domestic firms adopting the foreign technology, thus reducing the number of multinationals.

The intuition for (ii) hinges on competition effects. As the costs of technology adoption by downstream firms decreases, competition faced by multinationals becomes tougher, prompting multinational exit. Moreover, technology adoption by domestic firms decreases the equilibrium consumption share for goods produced with the foreign technology, thus reinforcing the negative effect on foreign entry.

Finally, as stated in (iii), a decrease in the cost of technology adoption by suppliers yields a decrease of the relative price index of inputs compatible with the foreign technology, and raises the number of multinationals.

Whereas domestic and multinational firms may generally coexist at equilibrium, it is also possible that the multinational firms are driven out of the market ($N_{MNE} = 0$). This type of equilibrium appears when the cost of adopting the foreign technology f_M is large for suppliers and F_M is low for domestic downstream firms. Analytically, $N_{MNE} = 0$ if and only if the relative mass of firms using

the foreign technology is equal to the relative mass of domestic firms adopting the foreign technology: $\frac{X_M}{X_D} = \left(\frac{\Phi_M}{\Phi_D}\right)^{-(k+1-\sigma)}$. At equilibrium, the fraction of domestic firms adopting the foreign technology does not depend on f_M , whereas the total mass of firms using the foreign technology at equilibrium is inversely proportional to $f_M^{\frac{\theta}{1-\theta}}$. Hence we obtain that N_{MNE} equals zero when f_M is above a certain threshold. Similarly, the right term decreases with F_M whereas the left term increases with F_M at equilibrium, thus the number of foreign entrants can be driven to zero for low cost of technology adoption by downstream domestic firms.

The intuition behind the latter result is close to the one developed in Markusen and Venables (1999). In their framework, a cumulative process of backward and forward linkages results in a wider availability of intermediates, which, in some cases, benefits domestic producers relatively more up to a point where multinational firms can be driven out of the market after entry. In our case, the possibility for domestic producers to incorporate the foreign technology after foreign entry can result in an increase of competitive pressure strong enough to force the foreign producers out.

3.3 Spillovers from FDI: empirical predictions and existing evidence

As has been discussed in the introduction, numerous empirical works have been recently devoted to the study of spillovers from foreign direct investment, thanks to both the renewed interest in the topic and the increasing availability of firm level data. The question asked in the empirical literature relates to whether increased foreign presence in the host economy is associated with productivity and/or technological improvements by domestic firms, including both suppliers and competitors. In this section we show that our framework is particularly well-suited to match the qualitative results provided by the empirical literature. We proceed by developing several comparative statics exercises and relating our results to some key patterns observed in the data. Given the large amount of existing works a comprehensive survey of the literature would be out of the scope of the present paper. We will mention a group of most representative empirical papers which are illustrative of the general findings. Interested readers are referred to the surveys in Gorg and Greenaway (2002), Lipsey (2002), Alfaro and Rodriguez-Clare (2004), Gorg and Strobl (2002), and Hanousek *et al.* (2010).²⁴

The empirical strategy followed by most works is reduced-form. It consists in regressing a measure of the productivity of domestic firms on a sector-level measure of foreign presence in the sector where the domestic firms operate (horizontal spillovers) and foreign presence in industries downstream to the domestic firms (vertical spillovers).²⁵ The sign and coefficient associated with the variable of foreign presence is interpreted as evidence of spillovers. All the work we mention as reference uses panel data, which allows the introduction of fixed effects (at the panel or firm level, depending on the study). Firm- or plant- level panel data enable the identification of the effect on foreign presence to rely on the evolution of within-firm (or plant) productivity, controlling for unobservable firm

²⁴The last two articles also present meta-analyses of the literature.

²⁵In this case usually input-output tables are used to identify vertical relationships across sectors.

characteristics and helping reduce concerns about selection issues.²⁶

In our framework the simplest measure of foreign presence is given by N_{MNE} , the number of multinational firms active at equilibrium. Notice however that “observed” foreign presence is endogenous. Variations in foreign presence relate to changes in structural parameters which also affect spillovers from FDI. We therefore adopt the following strategy. First, we describe how changes in these structural parameters affect spillovers at equilibrium. We focus on a few key policy variables: the fixed costs of multinational entry and technology adoption (downstream and upstream). However, these fixed costs are generally not observable in practice. For instance, cross-sectoral variations in foreign presence might reflect variations in barriers to foreign entry and also variations in the costs of technology adoption or in the relative productivity of foreign firms. Hence, in a second step, we relate our outcome variables to observed foreign presence in response to changes in underlying structural parameters.²⁷ By doing so, we provide a more precise link between our model and the various empirical studies on spillovers from foreign entry.

Vertical spillovers

We first analyze the effects on the productivity of local suppliers. By construction, an individual supplier adopting the foreign technology has a productivity gain: $\frac{\lambda_M}{\lambda_D} > 1$. This productivity premium is exogenous in our model. However, the number of suppliers adopting the foreign technology remains endogenous. According to equation (3) and Proposition 1, technology upgrading increases with the extent of foreign entry and technology adoption in the downstream industry. However, both foreign entry and technology adoption in the downstream industry are endogenous. In industry equilibrium, the relative mass of firms using each technology and relative consumption shares verify the properties announced in Proposition 4. We obtain the following:

Proposition 6 *The average productivity of upstream suppliers is:*

- (i) *decreasing in the cost of entry for multinational firms.*
- (ii) *decreasing in the cost of adoption of the foreign technology by upstream firms.*
- (iii) *increasing in the cost of adoption of the foreign technology by downstream domestic firms.*

As the costs of entry and technology adoption affect the extent of foreign entry at equilibrium (Proposition 5), we can further relate vertical spillovers to observed foreign presence:

Corollary 1 *The average productivity of upstream suppliers is positively related to observed foreign presence N_{MNE} when the exogenous fixed costs of multinational entry and/or technology adoption vary.*

²⁶Grog and Strobl (2002) highlight that cross-sectional studies tend to find positive effects whereas those based on panel data tend to find negative effects.

²⁷These results are expressed in Corollaries 1 to 6. In addition to changes in the fixed costs of technology adoption f_M , F_M and foreign entry F_{MNE} , we could be also explicit about the effect of a change in f_D , F_D , F_E or Φ_{MNE} . However, the conclusions from Corollaries 1 to 5 would be the same: the relationship between spillovers and foreign presence does not depend on which particular parameter is moving. An exception is Corollary 6 where the relationship between welfare and foreign presence depends on which parameter is affected.

The result that foreign presence has a positive effect on the observed productivity of domestic firms in supplying industries has been established by a number of empirical studies, following the pioneering work of Javorcik (2004) on Lithuania. For the case of developing economies these include Blalock and Getler (2007) for Indonesia, Kugler (2001) for Colombia, Joordan (2008) and Lopez-Cordova (2003) for Mexico, Javorcik and Spatareanu (2008) for Romania, and Liu (2008) for China. Evidence for developed countries include Driffield *et al* (2002) for the UK and Barrios *et al* (2009) for Ireland. These studies use panel data and are (excepting from the industry-level study of Joordan, 2008) at either the firm or plant level.

Horizontal spillovers

A second feature of interest to policymakers is the effect that incoming multinationals have on the performance of their domestic competitors, or “horizontal” spillovers. In our framework, heterogeneity is a key determinant of industrial structure. In particular, we have shown that the most productive firms adopt the foreign technology following multinational entry. We first focus on plants that do not adopt the foreign technology.

The productivity of plants producing under the D-technology is affected by the effect that multinational entry has on the costs of intermediate inputs. In particular, the change in productivity for a plant not upgrading after multinational entry is given by:

$$\frac{\Lambda_D}{\Lambda_A} = \left(\frac{P_D^{1-\eta}}{P_D^{1-\eta} + P_M^{1-\eta}} \right)^{\frac{1}{\sigma-1}} < 1$$

where Λ_A refers to the availability of inputs under autarky (without foreign entry and foreign technology). The larger the consumption share of goods produced with the foreign technology, the larger the *decrease* in productivity for firms producing with the domestic technology after foreign entry. Hence, this ratio satisfies the following properties:

Proposition 7 *The productivity of downstream firms using the domestic technology:*

- (i) *increases with the cost of entry for multinational firms.*
- (ii) *decreases with the cost of adoption of the foreign technology by downstream firms.*
- (iii) *increases with the cost of adoption of the foreign technology by suppliers.*

Corollary 2 The productivity of downstream firms using the domestic technology is negatively related to observed foreign presence N_{MNE} when the exogenous fixed costs of multinational entry and/or technology adoption vary.

All of these results go in the opposite direction compared to vertical spillovers. In particular, if technology adoption by downstream firms is prohibitively costly ($F_M = \infty$), the productivity of all domestic downstream firms is negatively correlated with foreign presence.

This corollary is consistent with empirical evidence showing negative horizontal spillovers, mostly for the case of developing countries. A widely cited example is Aitken and Harrison (1999) who study the case of the Venezuelan manufacturing industry. Using panel plant-level data, they find that domestic firms in sectors with more foreign ownership have lower TFP than those in sectors with less foreign presence. Other works finding qualitatively similar results include Haddad and Harrison (1993) for Morocco, Djankov and Hoekman (2000) for the Czech Republic, Lopez-Cordoba (2002) for Mexico and Damijan *et al.* (2001) for seven transition countries. This result is representative of the literature: in the survey by Gorg and Greenaway (2002), 33 out of 40 papers find either negative or not statistically significant effects. Similarly, Alfaro and Rodriguez-Clare (2004) state “The empirical evidence on whether FDI generates positive externalities for host countries is ambiguous, although the evidence for developing countries is more consistently pessimist”.

Further, most empirical studies look at the effect of foreign presence on the productivity of active domestic firms. Hence, they fail to capture a second channel through which multinationals might affect domestic productivity, which operates through firm selection and output reallocation. Hence, the previous results would be incomplete without characterizing the effect of foreign entry on the extent of firm survival, depending on abilities. The probability of survival Φ_D^{-k} is determined by the ability threshold Φ_D . Proposition 2 shows how fixed costs of multinational entry and technology adoption affect the survival rate of domestic firms. The following corollary holds:

Corollary 3 When the exogenous fixed costs of multinational entry and/or technology adoption vary, the ability threshold of survival Φ_D for domestic producers is negatively related to observed foreign presence.

This result reinforces the negative effect of foreign presence on the availability of domestic inputs.

Firm heterogeneity and horizontal spillovers

A branch of the empirical literature explicitly studies heterogeneity among spillovers’ recipients. Firms with high abilities (“absorptive capacity”, following Cohen and Levin, 1989 and 1990) tend to improve their performance following multinational entry whereas firms lacking such capacity are hurt by foreign presence.²⁸

Following this approach, we can look at how foreign presence impacts the observed productivity of plants adopting the foreign technology. The gain with respect to autarky is given by $\frac{\Lambda_M}{\Lambda_A}$. We can also look at the productivity gap between firms: $\frac{\Lambda_M}{\Lambda_D}$. Since both of them are increasing in the consumption share for goods produced with the foreign technology, we obtain the following proposition:

Proposition 8 *In the downstream industry, the productivity premium of the foreign technology compared to the domestic technology:*

²⁸A part of the literature has used patent citations to look for evidence on the transmission of technology from foreign to domestic firms. Fons-Rosen (2009) finds that investors in Central and Eastern Europe cite patents developed by foreign firms more often after the firms have located in the country. Cheung and Lin (2004) use provincial data for China and find that FDI increases the number of domestic patent applications.

- (i) decreases with the cost of entry for multinational firms
- (ii) increases with the cost of adoption of the foreign technology by downstream firms
- (iii) decreases with the cost of adoption of the foreign technology by suppliers

This result holds when we compare with the domestic technology in autarky (Λ_M/Λ_A) and with the equilibrium with foreign firms (Λ_M/Λ_D).

Corollary 4 The productivity premium of the foreign technology is positively related to observed foreign presence N_{MNE} when the exogenous fixed costs of multinational entry and/or technology adoption vary.

Our model provides a mapping from a firm’s intrinsic ability Φ_i to observed plant productivity $\Phi_i\Lambda_T$, which operates through self-selection into technologies and industry equilibrium effects. Increased entry by multinational firms yields a higher productivity for the most productive domestic firms. A testable implication of this result is that observed productivity dispersion should increase after foreign entry.

A number of empirical studies favor the idea that firms’ abilities, or absorptive capacity, matter for the determination of the sign of the spillover effect. A group of papers defines absorptive capacity as a low distance to the sector’s TFP leader. Girma *et al.* (2001) study the case of UK manufacturing. They find that spillovers are conditional on the distance between the firm’s productivity and the industry frontier. Firms with a technology gap of 10 per cent or less appear to increase productivity with increasing foreign presence in the industry, while firms with higher gaps seem to suffer reductions in productivity. Two other studies confirm this finding using UK data. Girma and Gorg (2007) use quantile regression methods. Their results support the idea that only firms with small productivity gaps receive positive spillovers. Girma (2005) uses threshold regressions and finds that firms with absorptive capacity above a threshold receive positive spillovers from FDI whereas spillovers for firms below the threshold are insignificant or negative. Similar evidence is provided for the case of Uruguay. Kokko *et al.* (1996) find that the spillover effect is negatively related to the technological gap between foreign and domestic firms, using firm-level data.

The role of absorptive capacity has been highlighted in an early macroeconomic study by Borenstein *et al.* (1998), that finds that inward FDI enhances growth only in countries with a level of human capital above a certain threshold. Schoors and van der Tol (2002) exploit this idea to use the level of human capital in the firm in order to proxy for absorption capacities and show that these increase the effect of FDI for a panel of Hungarian firms. Blalock and Gertler (2009) provide evidence for Indonesia which shows that firms with investments in research and development and firms with highly educated employees adopt more technology from foreign entrants than others. Looking for evidence of technology adoption, some works look at heterogeneity across sectors. Kathuria (2000), for example, analyzes FDI spillovers in manufacturing industries in India and concluded that these depend on the efforts of local firms to invest in learning or R&D activities. His empirical strategy is to break the sample across “scientific” and “non-scientific” subgroups. Aghion *et al.* (2009)

suggest that foreign entry in the UK is associated with productivity growth and innovation only in technologically advanced industries.

Finally, in a recent paper, Kee (2010) provides further support to the predictions of the model. Taking advantage of a rich dataset for bangladeshi firms in the garment sector that includes the identity of the firms' most important suppliers, she finds that only domestic firms which share their suppliers with multinational firms increase their productivity due to foreign entry.

Externalities between multinational firms

Whereas Corollary 4 endogeneizes the productivity advantage of domestic firms adopting the foreign technology, a similar result can be obtained for multinational firms since they rely on inputs compatible with the foreign technology:

Corollary 5 The productivity premium of multinational firms is positively related to observed foreign presence N_{MNE} when the exogenous fixed costs of multinational entry and/or technology adoption vary.

Corollary 5 then suggests that the "MNE" productivity premium that has been found by a large number of empirical studies²⁹ is endogenous and depends on the nature of the competition in vertically related markets. Further, it prompts an intuition that is consistent with findings from recent studies, showing that the productivity advantage of multinational firms in developing countries is positively related to the presence of other multinationals in the same sector. This is the case of manufacturing in Venezuela. Aitken and Harrison (1999) find that an interaction term between a foreign ownership dummy and foreign presence in the sector turns out positive and significant in explaining a plant's TFP. Liu (2008) replicates these results for China and also find a positive interaction term. Sabirianova *et al.* (2005) find that in the Czech Republic and Russia the productivity advantage associated with being a foreign firm increases with the share in total output that is produced by other foreign firms.

In cases where proximity to suppliers is crucial, the corollary provides a microfoundation for agglomeration forces among subsidiaries of multinational firms that have been found by a number of empirical works. In a recent study that exploits a dataset which covers nearly all the world populations of global firms, Alfaro and Chen (2009) find that vertical linkages are significant in explaining co-agglomeration between subsidiaries of multinational firms. Interestingly, vertical linkages do not have an impact on the co-agglomeration of multinational headquarters. Head *et al.*(1995) find that the location of Japanese multinationals across US states is strongly influenced by prior Japanese investments,³⁰ and Head and Mayer (2004) find similar results for the choice of Japanese affiliates

²⁹Griffith and Simpson (2001) and Criscuolo and Martin (2001) for the UK, Doms and Jensen (1998) for the US and Benfratello and Sembrenelli (2002) for Italy. The productivity advantage of MNEs' seems to be higher in the case of developing countries. Studies confirming this include Blomstrom and Wolff (1994) on Mexico, Haddad and Harrison (1994) on Morocco, Aitken and Harrison (1999) on Venezuela, Sjöholm (1999) on Indonesia and Kokko *et al.* (1994) on Uruguay, and Sabirianova *et al.* (2005) for the Czech Republic and Russia.

³⁰Interestingly, co-agglomeration is stronger for firms belonging to the same *keiretsu*, which is interpreted by the

across European regions. Evidence of multinational subsidiary clustering is provided by Bobonis and Shatz (2007) for the US and Crozet *et al.* (2004) for France.

3.4 Consumer welfare

We now discuss the welfare impact of multinational entry within our framework. At equilibrium, entry and exit of firms ensures zero profits for all types of firms. Hence, welfare analysis takes into account the effect on consumer surplus. Given the preferences structure, the price index of final goods provides a summary statistic for welfare. Denoting P_A the price index prevailing in autarky, and U_A the corresponding level of utility, we can ask the counterfactual question of how welfare changes from autarky to an equilibrium with multinational entry.

The change in welfare is given by the ratio of price indices: $\frac{U}{U_A} \equiv \left(\frac{P_D^{1-\eta} + P_M^{1-\eta}}{P_A^{1-\eta}} \right)^{\frac{1}{\eta-1}}$. At equilibrium, it is equal to:

$$\frac{U}{U_A} = \frac{\Phi_D}{\Phi_A} \left[\frac{P_D^{1-\eta}}{P_D^{1-\eta} + P_M^{1-\eta}} \right]^{-\frac{1}{\eta-1} \frac{1-\theta}{1+\theta}} > 1 \quad (20)$$

The proof is described in the (web-)appendix. Note that θ is assumed to be smaller than one if we consider a stable mixed equilibrium where both technologies co-exist.

Welfare gains $\frac{U}{U_A}$ can be decomposed into two terms: a productivity gain and variety gain. The first one is given by the ratio of the survival thresholds in the economy with multinationals and in autarky. As shown previously, this ratio is always larger than one when technology adoption by domestic firms is possible.

The term in brackets shows a second channel through which foreign presence affects domestic welfare, which operates through changes in the composition of consumption. By introducing their varieties into the economy, multinationals enhance consumer welfare, given imperfect substitution between varieties produced with the foreign technology and those produced with the domestic technology. This channel has been studied in the trade literature, that highlighted the gains from trade resulting from consumption of foreign varieties (Broda and Weinstein, 2001). The effect in this case is however different. The production of the new varieties happens in the host economy, which creates spillovers to local firms that lead to technology adoption and a further increase in the share of varieties produced with the foreign technology. Hence, horizontal spillovers magnify the effects of multinational production. Nevertheless, this mechanism is undermined by the segmentation of the upstream industry that reduces the range of inputs available for each technology. This is reflected in that the elasticity of the price index to welfare $\frac{1-\theta}{1+\theta}$ is lower than one. The total effect is however positive.³¹

authors as evidence that “supply relationships between Japanese firms and technological spillovers are stronger between members of the same keiretsu”.

³¹This second term is also similar to the welfare effect of trade in Arkolakis *et al.* (2008 and 2009). We can draw a parallel between the consumption share in goods produced with the domestic technology in our framework and the share of domestic goods in consumption in Arkolakis *et al.* (2008 and 2009). However, in our framework the share of goods produced with the domestic technology is not a sufficient statistic for welfare gains when downstream firms can adopt the foreign technology, as emphasized in Corollary 6.

Using the expressions relating fixed costs to multinational entry we can ask the related question of how welfare changes with variations in multinational entry and technology adoption by domestic firms. We obtain the following proposition (see web-appendix for the proof):

Proposition 9 *Consumer welfare:*

- (i) *decreases with the fixed costs of multinational entry.*
- (ii) *decreases with the fixed costs of technology adoption.*

Increased possibilities for domestic firms to adopt the foreign technology have a positive effect on consumer welfare. We have shown that, in equilibrium, a decrease in the cost of technology adoption F_M induces a decrease in the consumption share of goods produced with the foreign technology. However, the possibility of technology adoption increases the minimal ability threshold for domestic firms Φ_D to survive in equilibrium, which raises aggregate productivity and welfare. It can be shown (see web-appendix) that the positive effect always dominates. Similarly, a decrease in the cost of entry of multinational firms impacts positively on the share of final goods produced with the foreign technology, while decreasing the survival threshold for domestic firms Φ_D . The total effect is again positive.

We can further relate welfare gains to observed foreign presence:

Corollary 6 Consumer welfare is positively related to observed foreign presence when the cost of multinational entry decreases but negatively related to observed foreign presence when the cost of the foreign technology adoption decreases.

An interesting implication is that observed foreign presence is *not* a sufficient statistic for welfare when technology adoption by domestic downstream firms is allowed for. Micro-analyses on domestic firms' productivity and technology adoption seem to be necessary to estimate welfare gains.

4 Multiple equilibria and industrial development

Thus far we have analyzed the case with $\theta < 1$ which assures the stability of an equilibrium with the co-existence of both technologies. This condition is met for sufficiently low elasticity of substitution between goods produced with different technologies.³² We now analyze the case where $\theta > 1$. The mixed equilibrium is not stable any longer. Small changes in the cost of intermediates trigger large adjustments in consumption shares via their effects on consumer goods prices, which further affect suppliers' choices, reinforcing the effect on input prices and the cost differences across technologies. Multiplicity of equilibria arises. One of the two possible equilibria is characterized by firms producing only with the domestic technology, the origin in Figure 3. In such a case, multinationals are driven out of the market and the equilibrium is similar to autarky, with no firm producing with the foreign

³²When only a fraction of inputs are specific to each technology, a stable mixed equilibrium is obtained with a wider range of elasticities of substitution (see footnote 22).

technology. In the other stable equilibrium only firms using only the foreign technology are active ($\frac{X_M}{X_D} \rightarrow \infty$).

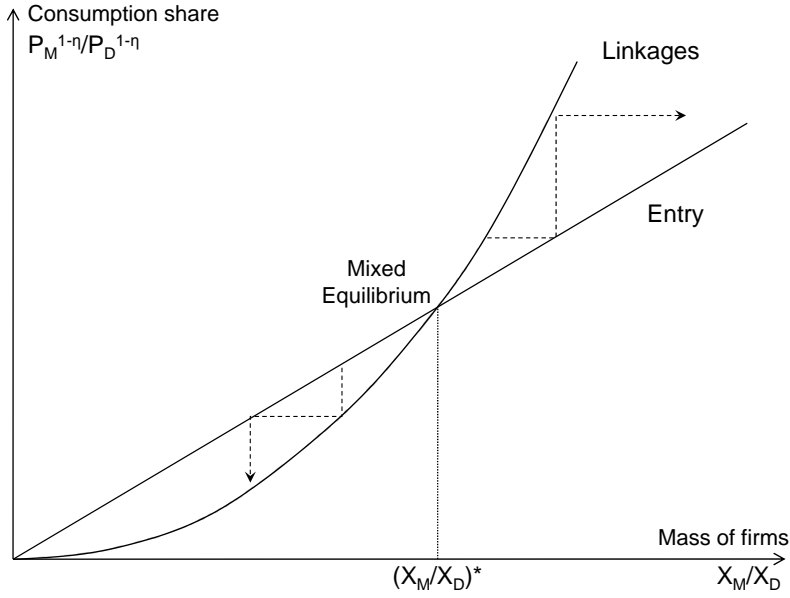


Figure 3: The case of multiple equilibria ($\theta > 1$)

Technological incompatibilities generate a barrier to entry for the multinational firms and the adoption of the foreign technology, which can be overcome only by strong changes in downstream and upstream industrial composition. As the Figure shows, only massive entry of multinationals (inducing sharp increases in the demand for inputs compatible with the M-technology) can take the economy to a cumulative causation path of technology adoption by domestic firms. Analytically, it requires the relative mass of firms using the foreign technology to be greater than the relative mass of firms corresponding to the (unstable) mixed equilibrium. It is characterized by:

$$\frac{X_M}{X_D} > \left(\frac{X_M}{X_D}\right)^*$$

This expression of the threshold $\left(\frac{X_M}{X_D}\right)^*$ is given by equation (17). However, with $\theta > 1$, the threshold is increasing in the cost of multinational entry, increasing in the cost of technology adoption by suppliers, and decreasing with the relative efficiency of the new technology.

Welfare analysis is given by the following expression:

$$\frac{U}{U_A} = \max \left\{ \frac{\lambda_M}{\lambda_D} \left(\frac{f_D}{f_M}\right)^{\frac{1}{\sigma-1}} \left(\frac{F_D}{F_M}\right)^{\frac{1}{\sigma-1} - \frac{1}{k}}, \frac{\lambda_M}{\lambda_D} \left(\frac{f_D}{f_M}\right)^{\frac{1}{\sigma-1}} \left(\frac{F_D}{F_{MNE}}\right)^{\frac{1}{\sigma-1}} \frac{\Phi_{MNE}}{\Phi_A} \right\}$$

The equilibrium with the foreign technology improves welfare only when the relative efficiency is large enough. When the costs of technology adoption and the costs of multinational entry are

high enough (or alternatively when the productivity of multinationals is low), the equilibrium with multinational entry would still be stable but it would generate a welfare loss compared to autarky: $\frac{U}{U_A} < 1$ (final goods would be more expensive).

Interestingly, in the unstable case, the equilibrium with technology adoption is characterized by either only adopting domestic firms, or only multinationals. Analytically, the condition for multinational firms to be forced out is the following:

$$\left(\frac{\Phi_{MNE}}{\Phi_A}\right)^{-k} > \left(\frac{F_M}{F_{MNE}}\right)^{\frac{k}{\sigma-1}} \frac{F_D}{F_M} \quad (21)$$

where $\left(\frac{\Phi_{MNE}}{\Phi_A}\right)^{-k}$ is the fraction of firms in autarky with ability larger than the one of multinational firms (Φ_A is the ability threshold under autarky as defined in Section 3.1). When this condition is not verified, only multinational firms survive at equilibrium.³³ In a model with heterogeneous multinational firms in which the productivity of the marginal foreign entrant decreases with the extent of foreign entry (as in Helpman *et al.*, 2004, and Chor, 2009), we would have both multinationals and upgrading domestic firms co-existing at equilibrium.

The fact that the stable equilibrium with technology adoption can be welfare-improving, while the initial autarky equilibrium remains stable, highlights the existence of a coordination failure. This result is similar to Rodriguez-Clare (1996) and Markusen and Venables (1999), showing that the entry of multinationals can trigger the development of local downstream and upstream industries.

5 Model extension with heterogeneous suppliers

We now discuss the case where upstream suppliers are heterogeneous in terms of ability. From an analytical viewpoint, allowing for heterogeneity in the upstream industry provides insights on the effect of multinational entry on reallocation and selection among local firms in supplying industries. From an empirical perspective, it allows us highlight an important feature of the interactions between multinationals and local suppliers in developing economies.³⁴

The setup we consider is the following. Upon payment of a fixed entry cost f_E measured in terms of the numeraire, entrepreneurs discover their ability φ drawn from a distribution $H(\varphi)$ which is assumed to be Pareto: $H(\varphi) = 1 - \varphi^{-\gamma}$. With knowledge of the firm-specific ability parameter, suppliers pay an additional fixed cost f_T to produce with the technology T. The unit cost of intermediate goods production compatible with technology T is $\frac{1}{\varphi\lambda_T}$.

³³This condition is stronger than the condition for the exit of multinational firms in the mixed equilibrium with lower θ , as discussed in Section 3.2. If $\theta < 1$, the condition (21) also implies that all domestic firms adopt the new technology ($\Phi_D = \infty$) and that all multinational firms exit. Hence it yields the same equilibrium as when $\theta > 1$.

³⁴The following extract from the UNCTAD World Investment Report 2001 (page 137) is illustrative of the idea that MNEs tend to work mainly with a subset of “best” suppliers: “[MNEs] tend to reduce the number of first-tier suppliers and enter into closer relationships with those that remain. These core suppliers are expected to have a capability to manufacture and supply – on a global basis – complex systems, to have independent design capacity and to solve problems jointly with the assembler. Such requirements make it more difficult for domestic suppliers in host countries to enter the supply chain (Suzuki’s affiliate in Hungary, for example, only negotiates with potential suppliers that are already ISO9000 and QS9000 certified)”.

We provide here the main insights provided by this version of the model, leaving the full derivation to the web-appendix. The relative price index of intermediate goods at equilibrium is given by:

$$\frac{\Lambda_M}{\Lambda_D} = \left(\frac{\lambda_M}{\lambda_D}\right)^{1+\theta_1} \left(\frac{X_M}{X_D}\right)^{\frac{\theta_1}{\sigma-1}} \left(\frac{f_D}{f_M}\right)^{\frac{\theta_1}{\eta-1}} \quad (22)$$

whereas the equilibrium relative consumption share is:

$$\frac{P_M^{\eta-1}}{P_D^{\eta-1}} = \left(\frac{\lambda_M^{\sigma-1} X_M}{\lambda_D^{\sigma-1} X_D}\right)^{\theta_2} \left(\frac{f_D}{f_M}\right)^{\theta_1} \quad (23)$$

with $\theta_1 = \frac{(\frac{\gamma}{\sigma-1}-1)\theta}{\theta+\frac{\gamma}{\sigma-1}}$ and $\theta_2 = \frac{(\frac{\gamma}{\sigma-1})\theta}{\theta+\frac{\gamma}{\sigma-1}}$. Comparison with the homogeneous suppliers case – equations (4) and (5) – is straightforward. The only differences are the elasticity coefficients θ_1 and θ_2 replacing θ and verifying $0 < \theta_1 < \theta_2 < \theta$. In the limit case $\gamma \rightarrow \infty$ of homogenous suppliers, we verify that both θ_1 and θ_2 equal θ as in equations (4) and (5).

In this new setup, technology adoption does not only depend on demand for inputs but also on suppliers' capabilities. Compared to the homogenous case, the margin of adjustment through technology adoption is smaller. Highly productive suppliers adopt both technologies while the lowest productivity suppliers exit the upstream industry, irrespective of demand conditions. Therefore, supplier heterogeneity decreases the response of technology adoption to the relative number of downstream firms using the foreign technology. As foreign entry in the downstream industry has a smaller impact on input prices, the business stealing effect is more likely to dominate and the mixed equilibrium is more likely to be stable. The stability condition for the mixed equilibrium in this case becomes $\theta_2 < 1$. Since $\theta_2 < \theta$, the stable solution appears in a broader range of parameters.

The main insights gained by introducing supplier heterogeneity into the model are summarized in the following proposition:

Proposition 10 *The following three statements are equivalent:*

- (i) *Adoption of the foreign technology is positively correlated with ability: $\varphi_M > \varphi_D$.*
- (ii) *The productivity premium of downstream firms using the foreign technology increases with ability dispersion in the upstream industry (i.e. decreases with γ).*
- (iii) *The relative fixed cost of technology adoption of the foreign technology is larger than the relative consumption share: $\frac{f_M}{f_D} > \frac{P_M^{1-\eta}}{P_D^{1-\eta}}$.*

The ranking $\varphi_M > \varphi_D$ is consistent with empirical evidence on supplier selection: multinational firms tend to deal with a small, selected base of “best” suppliers who comply with international standards. To the best of our knowledge, there is not as yet any rigorous econometric study available to test the proposition that only suppliers in the upper tail of the distribution of local capabilities qualify to cater to large foreign-owned corporations.³⁵ However, case study evidence points to the

³⁵Such a study might prove quite demanding in terms of the data required. One would have to know the ex-ante (i.e. before FDI) distribution of local capabilities and match the most capable suppliers with the ex-post distribution of contracts with multinationals.

notion that foreign affiliates tend to develop close relationships with a small base of local suppliers selected by a long, meticulous process. One characteristic often highlighted is the role played by local capabilities. Blalock and Gertler (2008) provide some anecdotal evidence from interviews with managers of American and Japanese companies operating in Indonesia. Among other things, these managers stated that: 1) Domestic supplier accreditation is a multistage process that takes years; 2) “Suitable” suppliers are hard to find. In line with this last point, foreign affiliates have been described as “talent scouts in search of local SMEs capable of becoming global suppliers to the firm” (OECD, 2002).

Then, an interesting question is how, under supplier self-selection, the dispersion of upstream firms’ abilities determine the productivity advantage of the foreign technology. Assuming that the ranking $\varphi_M > \varphi_D$ is verified, one corollary of point (ii) of Proposition 10 is that heterogeneity in the upstream industry benefits multinational firms. An empirical counterpart is that multinational entry should be larger in sectors supplied by upstream industries with higher ability dispersion.

This version of the model also allows us to derive some insights on the effect of foreign entry on exit and reallocation among suppliers. Assuming $f_M > f_D$, it can be shown that both ability thresholds φ_D and φ_M are above the ability threshold of survival in autarky. Moreover, assuming that at least one of the propositions above are verified (implying $\varphi_D < \varphi_M$), φ_D can be interpreted as a survival threshold reflecting *selection* effects. The following proposition (see web-appendix for a proof) describes how barriers to foreign entry and technology adoption affect the threshold φ_D :

Proposition 11 *The ability threshold φ_D in the upstream industry:*

- (i) decreases with the fixed cost of multinational entry.*
- (ii) decreases with the fixed cost of technology adoption by suppliers.*
- (iii) increases with the fixed cost of technology adoption by downstream firms.*

This selection effect reinforces the effect of vertical spillovers described in propositions 1 and 6. It can also be related to observed foreign presence (and tested) as described in the following Corollary.

Corollary 7 The ability threshold φ_D is positively related to observed foreign presence when the fixed costs of multinational entry and technology adoption vary.

6 Concluding remarks

The effects of foreign direct investment on the development of host economies are a matter of ongoing debate. To study this question, we develop a fully tractable model to study the impact of foreign entry on domestic firm performance and consumer welfare. Our model is built around the key assumption of “technological incompatibilities”: as suggested by empirical evidence, foreign firms are assumed to operate more advanced technologies which also require different types of inputs.

These differences in technologies affect the nature of backward and forward linkages between foreign firms and local suppliers. In cases where productive efficiency is determined by the availability of intermediate inputs, supplier technology choices determine the relative costs associated with each technology.

Our analysis delivers novel insights into the impact of foreign entry on domestic firms' productivity, technology adoption, survival, as well as consumer welfare. Our first result states that technological incompatibilities create strategic complementarities among plants using the same technology: the larger the share of plants operating a given technology, the wider the availability of compatible intermediate inputs, reducing unit costs. Hence, the exogenous technological advantage of the foreign technology is amplified at equilibrium by suppliers' choices. Since technology adoption is costly, firm heterogeneity plays a natural role: only the most productive firms generate enough revenues to find it optimal to adopt the foreign technology and to benefit from the decrease in the cost of intermediate inputs. Firms that do not engage in foreign technology adoption suffer from increased competition and from a reduction in the availability of inputs compatible with the domestic technology. The least productive ones are forced out. Spillovers are hence heterogeneous according to firms' inherent capabilities.

The predictions of our theoretical model match a number of key stylized facts drawn from the wide empirical literature on FDI spillovers. Our framework naturally delivers the co-existence of positive vertical spillovers from foreign presence (productivity improvements along the supply chain) coupled with weak or negative horizontal spillovers (effects on competitors' productivity and technology adoption). The explicit modeling of firm heterogeneity further allows us to qualitatively generate the empirical correlation between spillovers and indigenous firms' "absorptive capacity" that has been reported by a number of studies. Moreover, our framework naturally delivers the prediction that the multinational firms' productivity premium is endogenous and increases with the local presence of other multinationals. Finally, we highlight that foreign presence impacts consumer welfare both through a productivity effect and a variety effect, as goods produced with the foreign technology are imperfect substitutes in the eyes of consumers.

Although the externalities we highlight in the paper are transmitted through the market for intermediate goods, we believe that our argument is more general. The central mechanism would apply in a model where the foreign technology requires the acquisition of skills by domestic workers (for example, learning foreign language). Endogenous skill acquisition would determine the relative productivity of both technologies. Such an extension could be used in future work to study the labor markets effects of FDI.

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